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AN ESSAY *on the* DECLIVITIES OF MOUNTAINS.

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P. R. I. A.*

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AMONG the various causes to whose activity the planet we inhabit owes its present wonderfully diversified appearance, some undoubtedly exerted their influence from its very origin, and others at subsequent periods; of these last one at least, namely, the Noachian deluge, was universal in its operation, while the effects of many more were partial and local, such as those resulting from earthquakes, volcanos, particular inundations, &c.

Read April  
28, 1800.

In a general survey of the globe it is only to general causes whose operation was universal that our attention can be directed, the effects of partial causes being the proper objects of the geological history of those countries that were particularly affected by them.

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BUT to distinguish causes of the former class from those whose operation was more confined, it is necessary to discover some character by which their effects may unequivocally be discerned.

Now a general *uniformity*, or agreement in some particular circumstance in every part of the globe, seems to be a sure test of the operation of some general cause. The discovery of uniform appearances is therefore of primary importance in geological researches. In the present essay I shall confine myself to the investigation of one instance of this sort, namely, the *inequality of declivity* which the sides or flanks of mountains exhibit in every part of the globe hitherto examined according to the points of the compass to which they face, and are exposed.

THAT one part of almost every high mountain or hill is steeper than another could not have escaped the notice of any person who had traversed such mountains, but that nature in the formation of such declivities had any regard to different aspects or points of the compass, seems to have been first remarked by the celebrated Swedish Geologist Mr. Tilas in the 22d vol. of the Memoires of Stockholm for 1760.\* Neither Varenus, Lulolph nor Buffon in his Natural History published in 1748, have noticed this remarkable circumstance.

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\* See also vol. 25, Swed. Abhandl. p. 291, where Cronsted explains some obscure parts of Tilas's observation.

THE observation of Tilas however relates only to the extreme ends, and not to the flanks of mountains; with respect to the former he remarked that the *steepest* declivity always faces that part of the country where the land lies lowest, and the *gentlest* that part of the country where the land lies highest, and that in the southern and eastern parts of Sweden they consequently face the E. and S. E. and in the northern the W. The essential part of this observation extends therefore only to the general elevation or depression of the country, and not to the bearings of these declivities.

THE discovery that the different declivities of the flanks of mountains bear an invariable relation to their different aspects seems to have been first published by Mr. Bergman in his physical description of the earth, of which the second edition appeared in 1773. He there remarked that in mountains that extend from N. to S. the western flank is the *steepest* and the eastern the *gentlest*. And that in mountains which run E. and W. the southern declivity is the *steepest* and the northern the *gentlest*, vol. 2d. § 187.

THIS assertion he grounds on the observations related in his first vol. § 32, namely, that 1° in Scandinavia the Suevoberg mountains that run N. and S. separating Sweden from Norway, the western or Norwegian sides are the *steepest*, and the eastern  
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or Swedish the most moderate, the verticality or steepness of the former being to that of the latter as 40 or 50 to 4 or 2.\*

2dly. THAT the Alps are steeper on their western and southern sides than on the eastern and northern.

3dly. THAT in America the Cordelieres are steeper on the western side, which faces the Pacific Ocean, than on the eastern. But he does not notice a few exceptions to this rule in particular cases which will hereafter be mentioned.

BUFFON, in the first vol. of his Epochs of Nature published in 1778, p. 185, is the next who notices the general prevalence of this phænomenon, as far as relates to the eastern and western sides of the mountains that extend from north to south, but he is silent with respect to the north and south sides of the mountains that run from east to west; nay, he does not seem to have had a just comprehension of this phænomenon, for he considers it conjointly with the general dip of the regions in which these mountains exist. Thus he tells us, vol. 1st. p. 185, that in all continents the general declivity, taking it from the summit of mountains, is always more rapid on the western than on the eastern side, thus the summit of the chain of the Cordelieres is much nearer to the western shores than to the eastern; the chain which divides the whole length of Africa from the Cape of Good Hope

\* The verticality of the sides is inversely as the length of the descent.]

Hope to the mountains of the Moon is nearer, he says, to the western than to the eastern seas; of this however he must have been ignorant, as that tract of country is still unknown.

THE mountains which run from Cape Comorin through the peninsula of India are, he says, much nearer to the sea on the east than on the west; he probably meant the contrary, as the fact is evidently so, and so he states it in the 2d vol. p. 295; the same he tells us may be observed in islands and peninsulas, and in mountains,

THIS remarkable circumstance of mountains was notwithstanding so little noticed that in 1792 the author of an excellent account of the territory of Carlsbad in Bohemia tells us he had made an observation, which he had never met with in any physical description of the earth, namely, that the southern declivity of all mountains was much steeper than the northern, which he proves by instancing the *Erzgebirge* of Saxony, the Pyrenees, the mountains of Switzerland, Savoy, Carinthia, Tyrol, Moravia, the Carpathian and Mount Hæmus in Turkey, 2, Bergm. Jour. 1792, p. 385, in the note.

HERMAN in his Geology, published in 1797, p. 90, has at least partially mentioned this circumstance, for he says that the eastern declivities of all mountains are much gentler and more thickly covered with secondary strata, and to a greater height, than the  
western

western flanks, which he instances in the Swedish and Norwegian mountains, the Alps, the Caucasian, the Appenine and Ouralian mountains; but the declivities bearing a southern or northern aspect he does not mention.

LA METHERIE, in the 4th vol. of his Theory of the Earth, of which the second edition appeared in 1797, a work which abounds in excellent observations, p 381, \* produces numerous instances of the inequality of the eastern and western declivities, but scarce any of the northern and southern, whose difference he does not seem to have noticed, but he makes a remark which I have not seen elsewhere, that the coasts of different countries present similar declivities.

WITH regard to eastern and western aspects he thinks that a different law has obtained in Africa from that which has been observed in other countries, for in that vast peninsula he imagines the eastern declivities of mountains are the steepest and the western the gentlest. Of this however he adduces no other proof but that the greatest rivers are found on the western side; this proof seems insufficient, as, if mountains be situated far inland, great rivers may flow indiscriminately from any side of them, and sometimes few rivers flow even from the side whose descent is most moderate, for instance, from the eastern side of the mountains of Syria; the Elbe and the Oder, two of greatest rivers in Germany,

\* It is to be regretted that he scarce ever quotes his authorities.

Germany take their course from the western sides, the first of the Bohemian and the other of the Moravian mountains which yet are the steepest; many originate from lakes, as the Shannon with us; many take such a winding course that from a bare knowledge of the place of their disembogement it is impossible to judge from what side of a mountain they issue, if from any; their course at most discovers the depression of the general level of the country.

IN 1798, the celebrated traveller and circumnavigator, John Reinhold Foster, published a geological tract which merits so much more attention as all the facts were either observed by himself or related to him by the immediate observers. In this he states as a fact universally observed, that the south and south east sides of almost every mountain are steep, but that the north and north west sides are gently covered and connected with secondary strata in which organic remains abound, which he illustrates by various instances, some of which have been already, and others will presently be mentioned.

AT present this fact attracts the greatest attention being obviously connected with the original structure of the globe and clearly proving that mountains are not mere fortuitous eruptions unconnected with transactions on the surface of the earth as has of late been confidently advanced.

I SHALL now state the principal observations relative to this object that have been made in different parts of the world.

*In Europe.*

1° THE mountains that separate Sweden from Norway extend from north to south, their western sides are *steep* and the eastern *gentle*, 1. Bergm. Erde Beschreib. p. 157.

2° THE Carpathian mountains run from E. to W. their southern sides towards Hungary are steep, their northern towards Poland moderate, Foster, § 46.

3° Doctor Walker, professor of natural history at Edinburgh, observed that the coasts and hills of Scotland are steeper and higher on the western side than on the eastern Jamison Mineralogy of Shetland, p. 3, However Jamison observed that the south side of the isle of Aran is the lowest and the north side the highest, p. 51.

4° THE mountains of Wales are gentle on the eastern and steep on the western sides.

5° THE mountains of Parthery in the county of Mayo are steep on the western side.

6° THE mountains which separate Saxony from Bohemia descend gently on the Saxon or northern side, but are steep on the  
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Bohemian or southern side Charpent, p. 75. The southern declivity is to the northern as six to two, 2d Bergm. Journ. 1792, p. 384 and 385.

7° THE mountains which separate Silesia from Bohemia run nearly from E. to W. yet are steeper on the northern or Silesian side than on the opposite Bohemian, Affemann's *Silesia*, 335. Such branches as run from N. E. to S. W. have their western covered with primordial strata and consequently less steep, 4, New Roz. p. 157.

8° THE Meißener in Hessia is steeper on the N. and E. sides which face the Warra than on the south and western, 1, Bergm. Journ. 1789, p. 272.

9° THE mountains of the Hartz and Habichtswald are steep on the south and gentle on the northern sides, Foster §. 46.

10° THE Pyrenees which run from E. to W. are steeper on the southern or Spanish side, Carbonieres XIII.

11° THE mountains of Crim Tartary are gentle on the northern and steep on the southern sides, Foster, *ibid.*

*In Asia.*

12° THE Ourals which stretch from N. to S. are far steeper on western than on the southern sides, Herman *Geologie*, p. 90, and 2d *Ural Beschreib.* p. 389.

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13<sup>o</sup> THE mountain of Armenic to the west of the Ourals is steep on its E. and N. sides, but gentle on the southern and western, 1. Pallas Voy. p. 277.

14<sup>o</sup> THE Altaifchan mountains are steep on their southern and western sides, but gentle on the northern and eastern, Foster, *ibid.* and Herman 2d Ural Beschreib. p. 390 in the note.

15<sup>o</sup> So also are the mountains of Caucasus, 3d Schrift. Berl. Gefelsch. 471.

16<sup>o</sup> THE mountains of Kamskatka are steep on the eastern sides, Pallas, 1 Act. Petropol. 1777, p. 43.

17<sup>o</sup> THE Ghauts in the Indian peninsula are steep on the western sides.

18<sup>o</sup> THE mountains of Syria which run from N. to S. skirting the Mediterranean, are said to be steeper on the western side facing the Mediterranean, 4. La Metherie, p. 380.

*In America.*

THE Cordelieres run from N. to S. their western flanks towards the Pacific are steep, their eastern descend gradually.

IN Guiana there is a chain of mountains that run from E. to W. their southern flanks are steep, their northern gentle, Voyages de Condamine, p. 140.

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To assign the causes of this almost universal allotment of unequal declivities to opposite points and why the greatest are directed to the west and south, and the gentlest on the contrary to the east and north it is necessary to consider,

1° THAT all mountains were formed while covered with water.

2° THAT the earth was universally covered with water at two different æras, that of the creation, and that of the Noachian deluge.

3° THAT in the first æra we must distinguish two different periods, that which preceded the appearance of dry land, and that which succeeded the creation of fish, but before the sea had been reduced nearly to its present level; during the former, the primæval mountains were formed, and during the last, most of the secondary mountains and strata were formed.

4° THAT all mountains extend either from E. to W. or from N. to S. or in some intermediate direction between these cardinal points which need not be particularly mentioned here, as the same species of reasoning must be applied to them, as to those to whose aspect they approach most.

THESE preliminary circumstances being noticed, we are next to observe that during the first æra, this vast mass of water moved  
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in two general directions, at right angles with each other, the one from E. to W. which needs not to be proved, being the course of tides which still continue, but were in that ocean necessarily stronger and higher than at present: the other from N. to S. the water tending to those vast abyſſes then formed in the vicinity of the ſouth pole, as ſhewn in my former eſſays. Before either motion could be propagated a conſiderable time muſt have elapſed.

Now the primæval mountains formed at the commencement of the firſt æra, and before this double direction of the waters took place, muſt have oppoſed a conſiderable obſtacle to the motion of that fluid in the ſenſe that croſſed that of the direction of theſe mountains. Thus the mountains that ſtretch from N. to S. muſt have oppoſed the motion of the waters from E. to W. this oppoſition diminiſhing the motion of that fluid diſpoſed it to ſuffer the earthy particles with which in thoſe early periods it muſt have been impregnated to chryſtallize or be depoſited on theſe eaſtern flanks, and particularly on thoſe of the higheſt mountains, for over the lower it could eaſily paſs; theſe depoſitions being inceſſantly repeated at heights gradually diminiſhing as the level of the waters gradually lowered, muſt have rendered the eaſtern declivities or deſcent, gentle, gradual and moderate, while the weſtern ſides receiving no ſuch acceſſions from depoſitions muſt have remained ſteep and craggy.

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AGAIN, the primeval mountains that run from E. to W. by opposing a similar resistance to the course of the waters from N. to S. must have occasioned similar depositions on the northern sides of these mountains against which these waters impinged, and thus smoothed them.

WHERE mountains intersect each other in an oblique direction, the N E side of one range being contiguous to the S W. flanks of another range, there the afflux of adventitious particles on the north east side of the one, must have frequently extended to the S. W. side of the other, particularly if that afflux were strong and copious; thus the *Erzgebirge* of Saxony, which run from W. to E. have their N.E. sides contiguous to the S W. side of the *Riesengebirge* that separate Silesia from Bohemia, and hence these latter are covered with the same beds of Gneiss, &c. as the northern sides of the Saxon, and thereby are rendered smooth and gentle comparatively to the opposite side, which being sheltered, remains steep and abrupt, which explains the seventh observation.

THE causes here assigned explain why the covering of adventitious strata on the highest mountains is generally thinnest at the greatest height, and thickest towards the foot of the mountain, for the bulk of the water that contained the adventitious particles being proportioned to its depth, and the mass of earthy  
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particles with which it was charged, being proportioned to the bulk of water that contained them, it is plain, that as the height of water gradually decreased, the depositions from it on the higher parts of the mountains must have been less copious than on the lower, where they must have been oftener repeated.

HENCE 2<sup>o</sup> granitic mountains, generally the most antient, frequently have their northern or eastern sides covered with strata of gneiss or micaceous schistus, and this often with argillite, or primæval sand-stone, or lime-stone, these being either of somewhat later formation or longer suspendible in water.

HENCE 3<sup>o</sup> different species of stone are often found at different heights of the same flank of a mountain, according as the water which conveyed these species, happened to be differently impregnated at different heights; during the first æra its depositions formed the primitive stony masses, but after the creation of fish, lime stone, sand-stone, facillites and secondary argillites in which piscine remains are found, were deposited. But during the second æra, viz that of the Noachian deluge, by reason of the violence and irregularity of its aggression, the depositions were more miscellaneous and are found at the greatest heights; yet in general they may well be distinguished by the remains of land animals, or of vegetables, or of both, which they present in their strata (or at least by the impressions of vegetables which they bear) as these must have been conveyed after the earth had  
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been inhabited. But mountains regularly stratified bearing such remains, for instance the Carboniferous, cannot be deemed to have been formed in a period so tumultuous. During this deluge the waters also held a different course, proceeding at first from south to north and afterwards in both opposite directions in our western hemisphere as shewn in treating of that catastrophe in my second essay.

HENCE, and from various contingent local causes, as partial inundations, earthquakes, volcanos, the erosion of rivers, the elapion of strata, disintegration, the disruption of the lofty mounds by which many lakes were antiently hemmed in, several changes were produced in particular countries that may at first sight appear, though in reality they are not, exceptions to the operation of the general causes already stated.

THUS the mountains of Kamiskatka had their eastern flanks torn and rendered abrupt by the irruption of the general deluge probably accompanied by earthquakes. And thus the Meissener had its E. and N. flanks undermined by the River Warra, as Werner has shewn; thus the eighth and sixteenth observations are accounted for, as is the thirteenth by the vast inundations so frequent in this country, i. Pallas, p. 172, which undermined or corroded its E. side while the western were smoothed by the calcareous depositions from the numerous rivers in its vicinity.

HENCE 4<sup>o</sup> We see why on different sides of lofty mountains different species of stones are found, as Pallas and Saussure have observed, 2. Sauss. § 981, a circumstance which Saussure imagined almost inexplicable, but which Dolomieu has since happily explained by shewing that the current which conveyed the calcareous substances to the northern, eastern and N. eastern sides of the Alps, for instance, was stopped by the height of these mountains, and thus prevented from conveying them to the southern sides, and thus the N. eastern sides were rendered more gentle than the opposite, 3, New Roz. p. 425, conformably to the theory here given.

HENCE 5<sup>o</sup> Where several lofty ridges run parallel to each other it must frequently happen that the external should intercept the depositions that do not surmount them, and thus leave the internal ridges steep on both sides.

HENCE 6<sup>o</sup> Low granitic or other primitive hills are frequently uncovered by adventitious strata on all sides as at Phanet in the county of Donegal, or are covered on all sides; the impregnated waters either easily passing over them or stagnating upon them according to the greater or lesser rapidity of its course and the obstacles it met with.

THE two fold motion of the antient ocean is noticed both by Buffon and Bergman, but neither of them have deduced from  
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it the true explanation of the phenomena of which we here treat; Buffon attributes the formation of secondary mountains to deposition or sediments from the sea after the existence of fish, 1, *Epoques*, p. 143, in 8vo. which he says invested the bases of mountains without noticing any distinction of sides, p. 144 and 170. He thinks these sediments were equally conveyed from both poles towards the *Æquator*, for it is the *Æquatorial* regions that he thinks those mighty caverns opened towards which the primitive ocean was impetuously borne and in which it was ingulphed, p. 181, 182 and 183. If so, similar declivities should be formed on the southern as on the northern sides of mountains, which is contrary to the observed facts. His explanation of the eastern and western declivities is defective and erroneous, for he attributes the abruptness of the western sides to the erosion of the coasts on that side (an erosion that exists only in fancy) and the smoothness of the eastern to the gradual desertion and retreat of the sea on that side, p. 184 and 185, a retreat equally fictitious as De Luc has well shewn. Whereas since the general motion of the sea is from E. to W. if the erosion were of either side it should rather be on the eastern than on the western; besides, if the gentle declivities of the eastern sides of mountains arose from the gradual retreat of the sea the petrifications of the secondary mountains thus formed should consist of such shell fish as inhabit shallow

feas or shores, whereas they consist chiefly of those called *pelagica* which inhabit the greatest depths.\*

WITH respect to the eastern and western declivities, Mr. Bergman's account of the origin of their inequality agrees exactly with mine, 2. Bergm. Erdeklotet § 183 and 187, but he fails in accounting for the inequality of the northern and southern, for he supposes the course of the waters to tend equally from both poles towards the Æquator which would render the depositions equal on both sides, which is contrary to observation.

\* 2. Bergm. Erdekugel, p. 315.